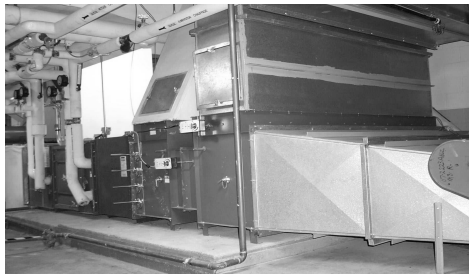
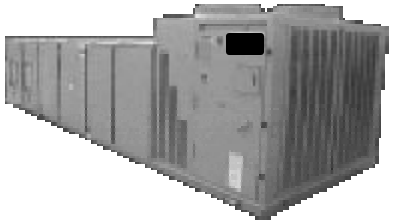
EMCS Assisted Commissioning Tool For Variable Air System





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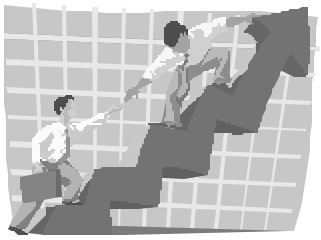
dchoinie@nrcan.gc.ca

Canadian Contribution:

- IEA Annex 40, Commissioning of Building HVAC Systems for Improved Energy Performance
- IEA Annex 34, Computer-aided Evaluation of HVAC System Performance: the Practical Application of Fault Detection and Diagnosis Techniques in Real Buildings
- Acknowledgements: PERD, Natural Ressources Canada

WHY?
Commissioning,
Re, On Going-Commissioning,
Energy Management

- 15-30% energy savings
- Improve comfort
- Facilitate maintenance
- Continuity in energy savings measures
- Extend HVAC equipment life

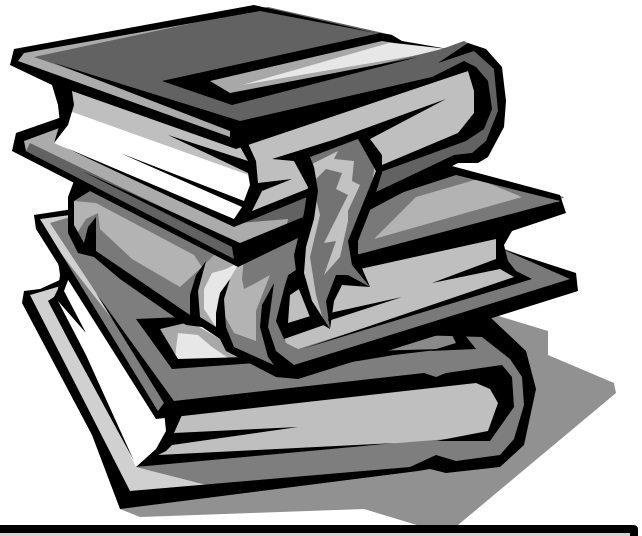


Outline

- EMCS Assisted Cx Tool
- Methods
- Results
- Next steps

Definitions

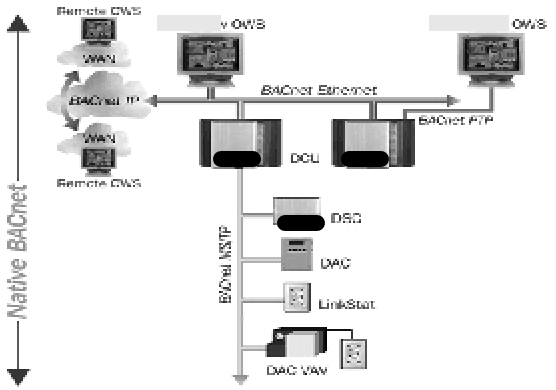
- On-going Commissioning Tool

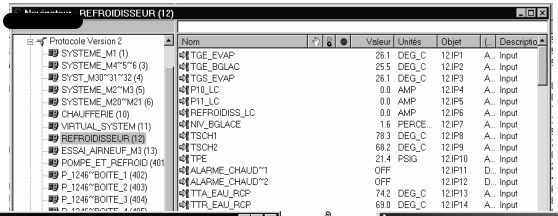


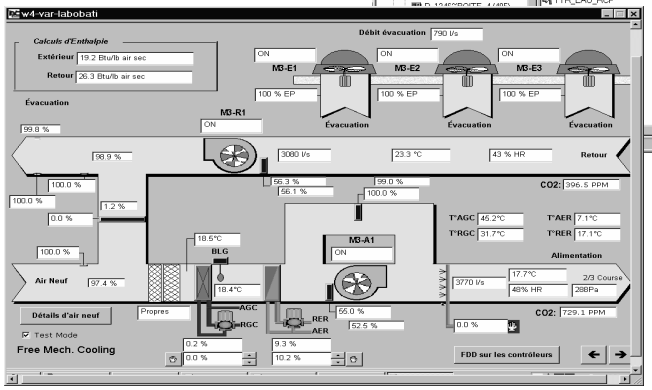
- Detect unsatisfactory performance and diagnose faults
- Function of installed equipments and occupation type:
  - Optimize energy use, while maintaining or improving occupant comfort and productivity;

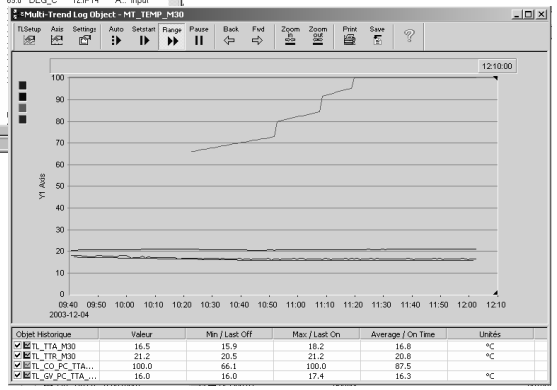
EMCS Today

- Good to control system
- Good to allow visualization in real time (if graphics are well configurated)
- Manage simple alarms
- Simple monitoring

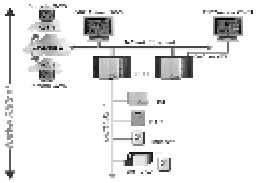








Energy Management and Control System
Building-Plants-Systems-Rooms



Feedback To EMCS

DABO TOOL
Commissioning
+ DATABASE

Artificial Intelligence Tech.

Component level:
•Defective devices

FDD VAV, AHU, Rooftop, H&C networks

System level:
•Optimisation: setpoint and sequence of operation

FDD
Systems level

Global analysis:
Energy efficiency projects

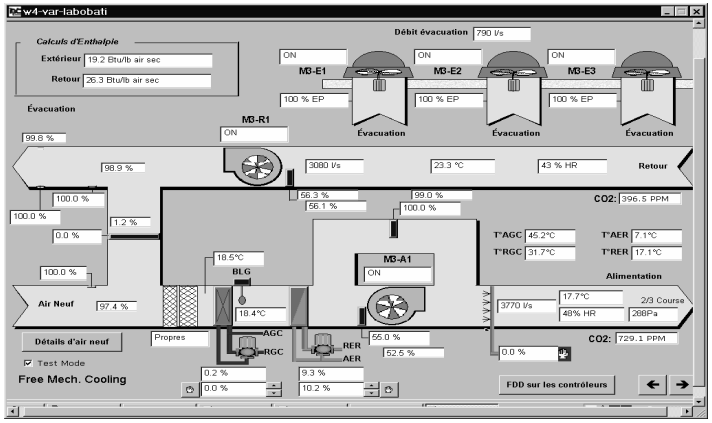
ENERGY AUDITING

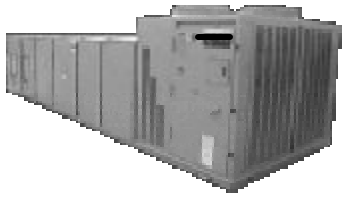
Operator, Energy manager

REPORT GENERATOR

Fault Detection and Diagnosis: Component Level

- Sensor (temperature, humidity, air flow, pressure, CO_2, current)
  - incorrect reading, complete failure
- Damper, valve, actuator
  - stuck, position, minimum, leakage
- Coil, humidifier, fan
  - undercapacity
- Controller
  - logic, tuning, signal, unstable (setpoint, output)
- Point in manual





Fault Detection and Diagnosis: System Level

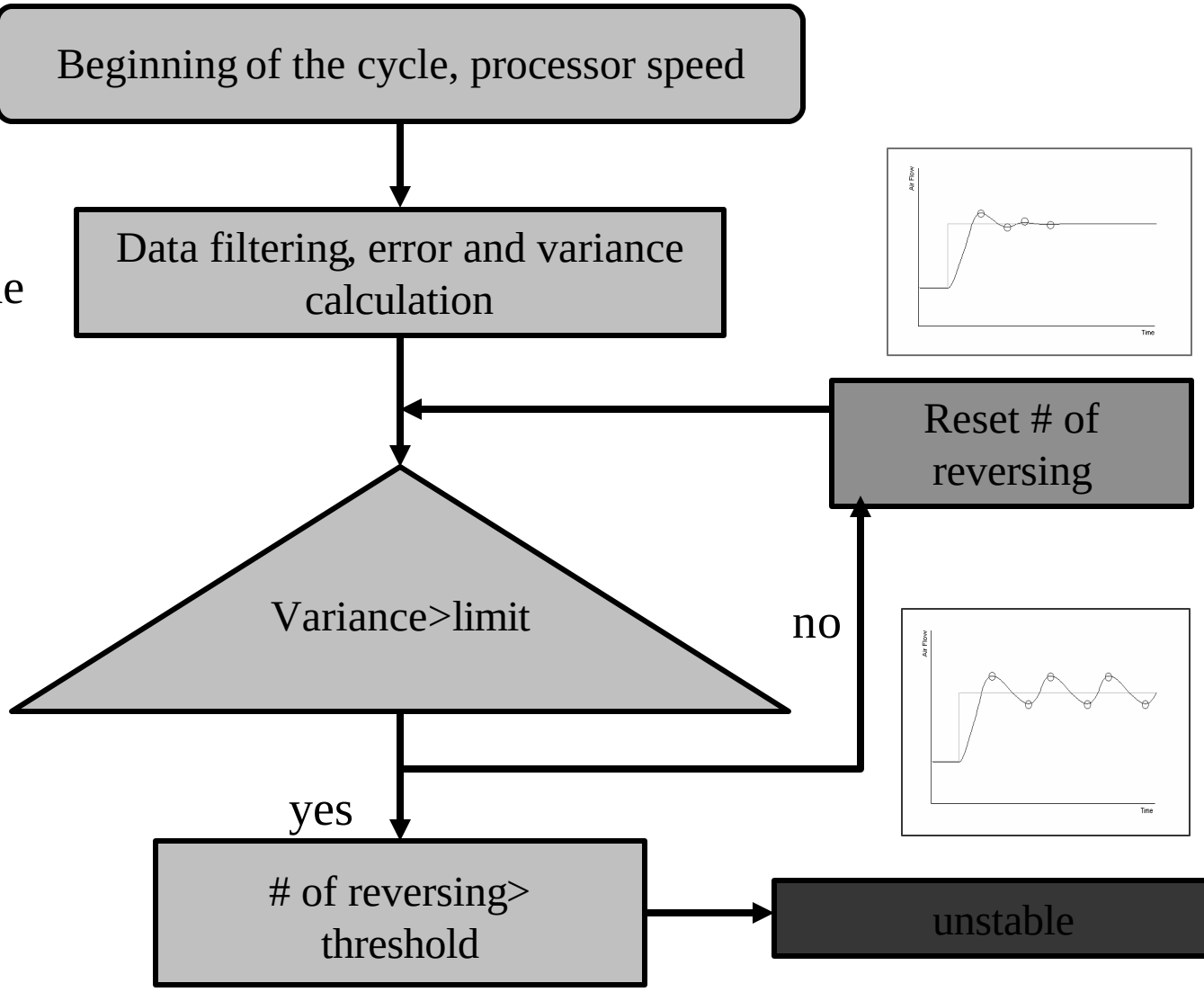
- Detection of:
  - under or over design components, systems and plants
  - Non optimum set points
    - Temperature, pressure, humidity, ventilation, start-up time
  - Inappropriate sequence of operation
  - Poor energy management and peak load control

Energy Auditing

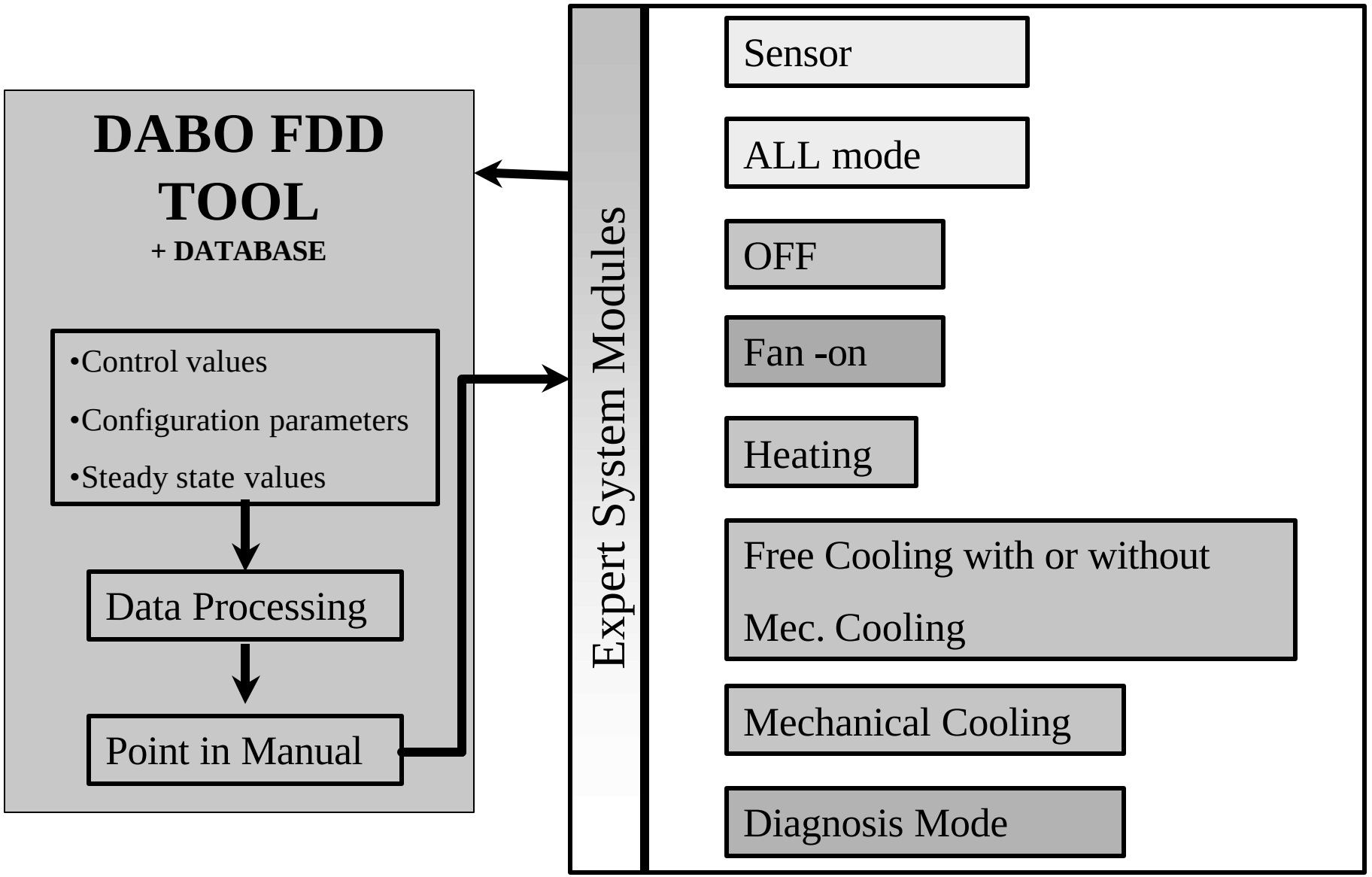
- Energy profile (Day, month and year)
  - Equipment level (TERMINAL, AHU, Power plant)
  - Building level (electric, gas, oil meter?)
  - Include adjustment and influence factors
- Monitoring of energy saving measures
- Historical database for energy audit or retrofit
- Real time energy audit
- Link to accounting manager software
- FDD at building level (Tariffs, reference profile)

Embeded Steady State Detector

- Inputs:
  - Setpoint and value
  - Control output and bias
- Configuration inputs
  - Filtering rate
  - Variance limit
  - Threshold # of reversing



FDD Architecture, Component Level



Fault Detection and Diagnosis: System Level

- Indice of performance:
  - With existing control points, find an equation that:
    - Characterize devices condition
    - Characterize devices utilisation
    - **Allow comparison between devices**

✵Utilisation factor ✵

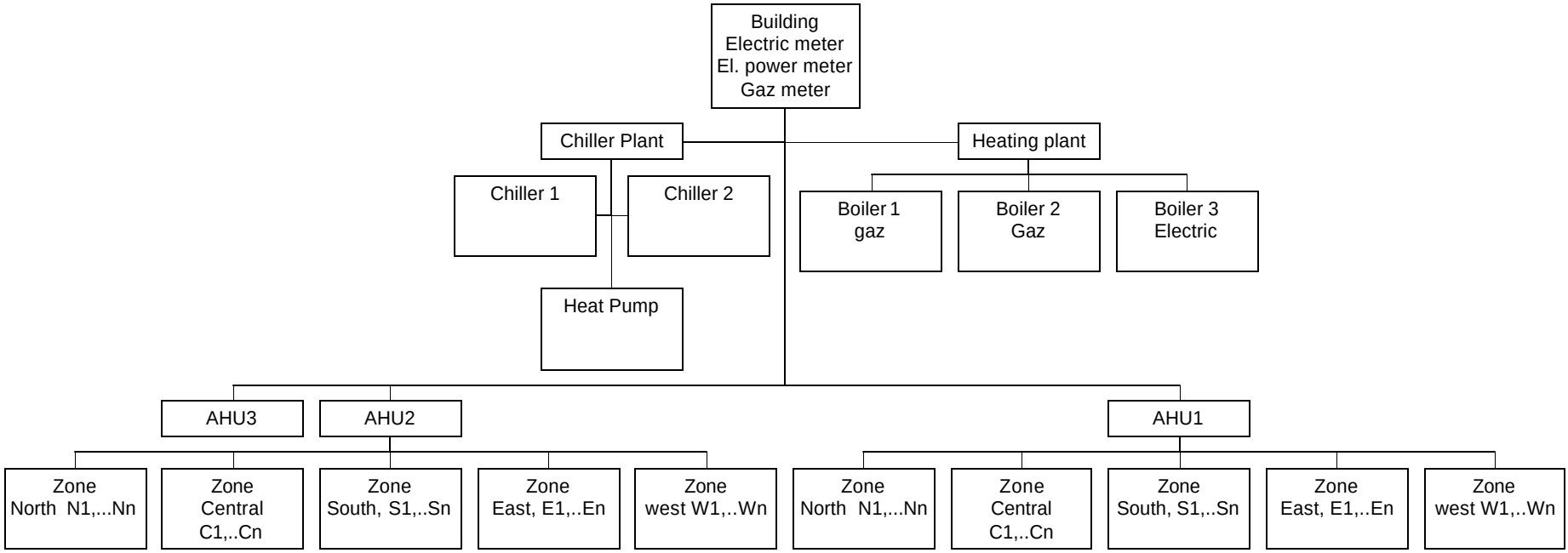
- Method:
  - Analysis of Utilisation Factors
  - Diagnosis method: Statistics and Rule base

Performance indice: Room Level

Indice	Optimisation, performance report	Detection,
Temperature (%)		Under and overdesign components Poor sequence of operation
Air quality (%)	% of fresh air	
Damper position (%)	SAP	
Cooling (%)	SAT, SAP	
Heating (%)	SHWT	
Reheating (%)	SHWT	
Airflow (%)	SAP, SAT	
Fault Code		
Fault type	Confort, energy, life cycle	

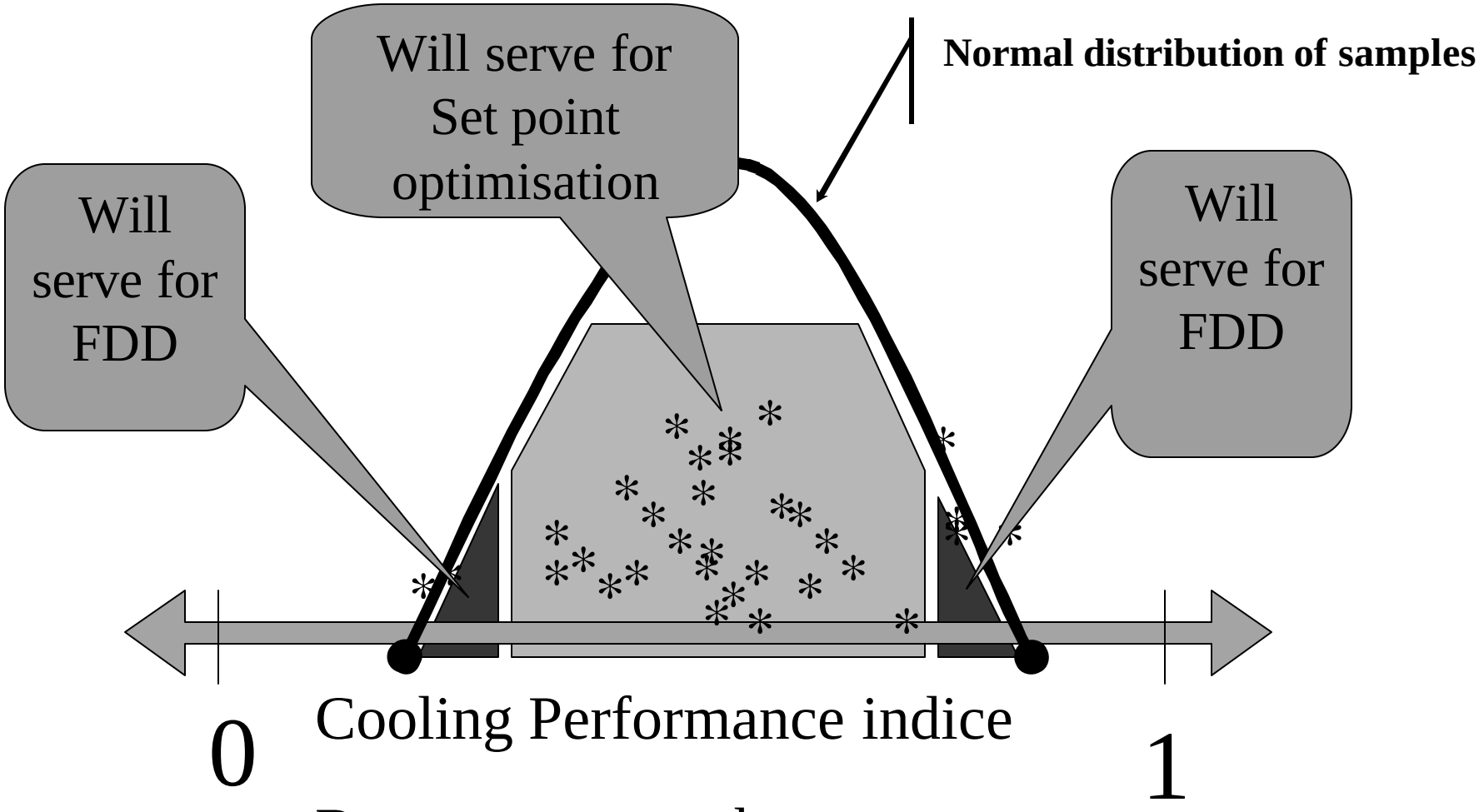
Performance indice: Utilisation Factors, System level

- Supply, return Fan indice (vsd%)
- Airflow (airflow)
- Heating coil indice (%HC, Time on)
- Cooling coil indice (%CC, Time on)
- Reheat coil indice (%RHC, Time on)
- Humidifier indice (%HUM, Time on)
- Fresh air indice (%, calculation)
- Cooling indice
- Heating indice



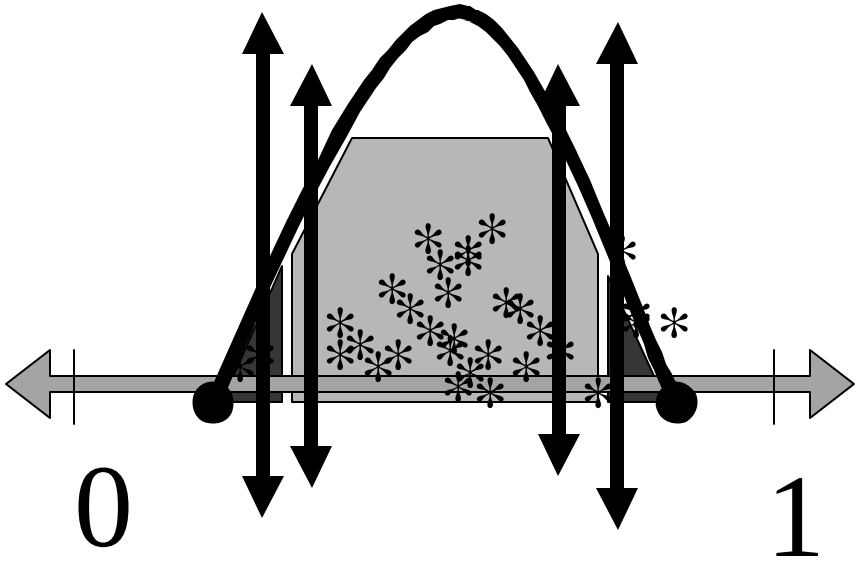
U.F analysis: **real time, 1H, 1 working periodetc..**

- Between rooms in a same zone and AHU
- Between AHUs components (CC, HC)
- Between Chillers, Boilers



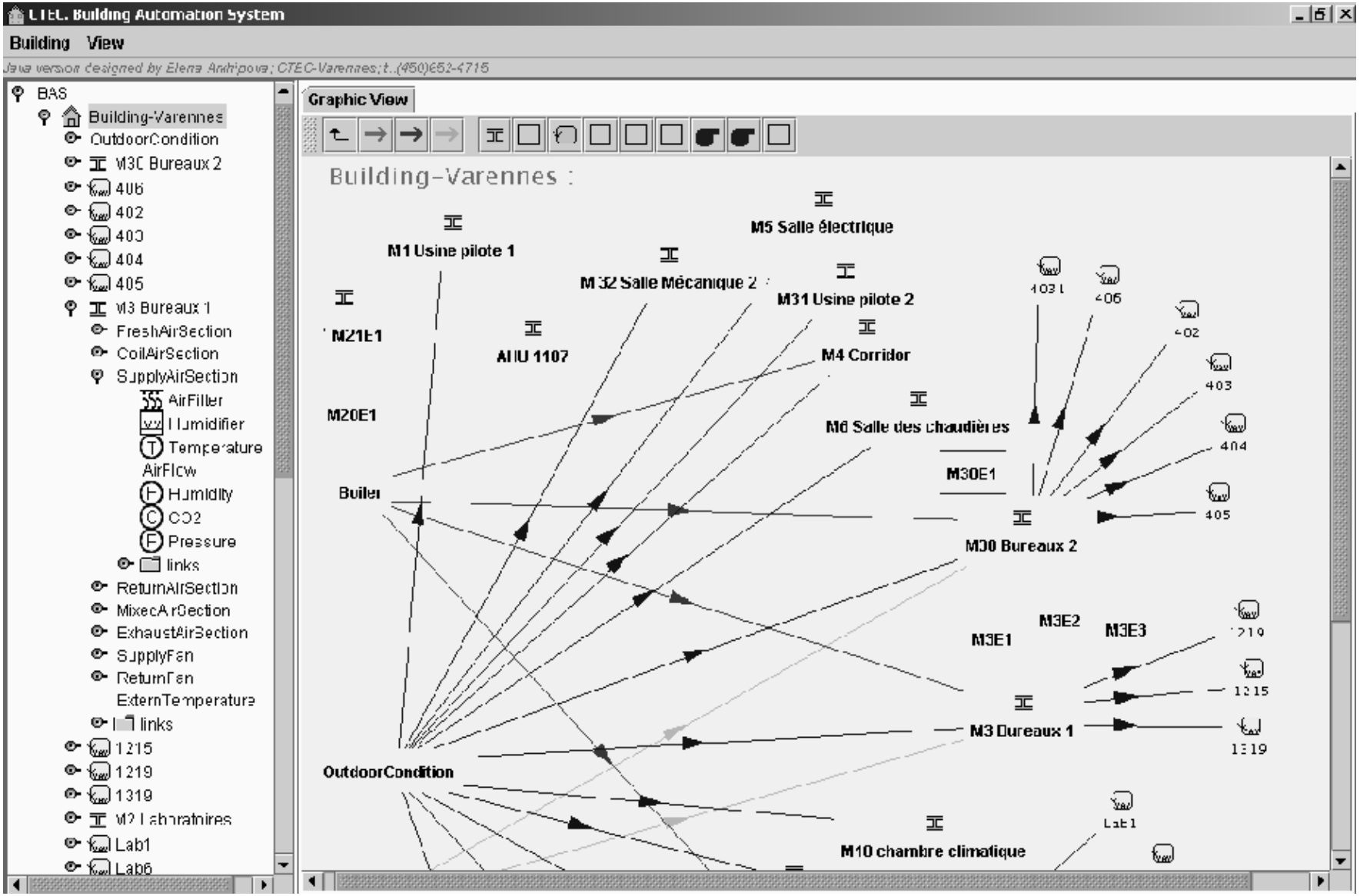
- Sort by Statistic methods, filters, etc
  - Depend, # and type of samples

Calculation of Warning and Critical Limit Parameters, Reference Patern

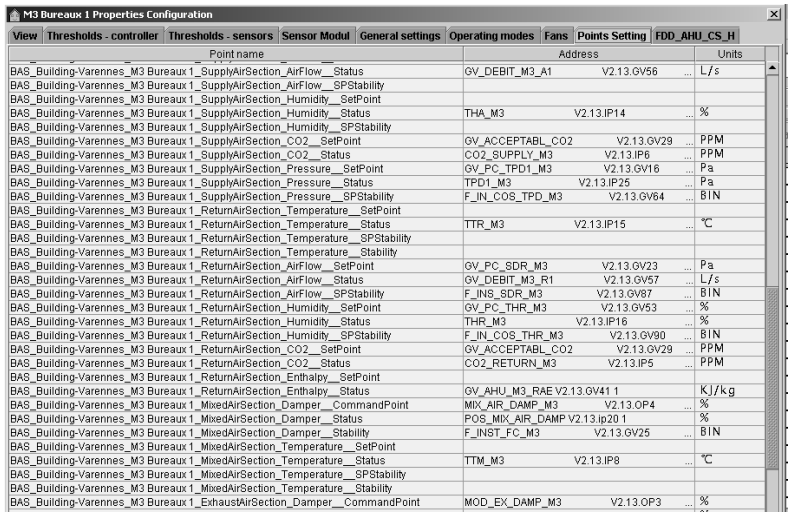


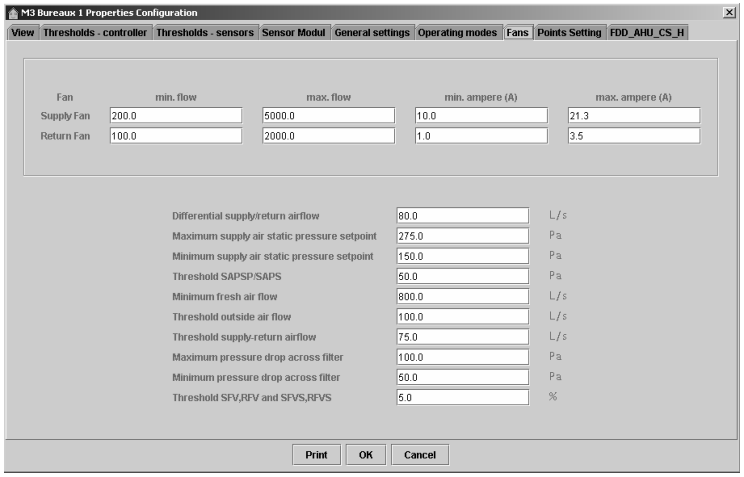
- Filter option in statistic calculation :
  - Devices (one or all)
  - Date
  - Hour
  - Outside air temperature
  - Outside air humidity
  - Solar (if sensor is available)

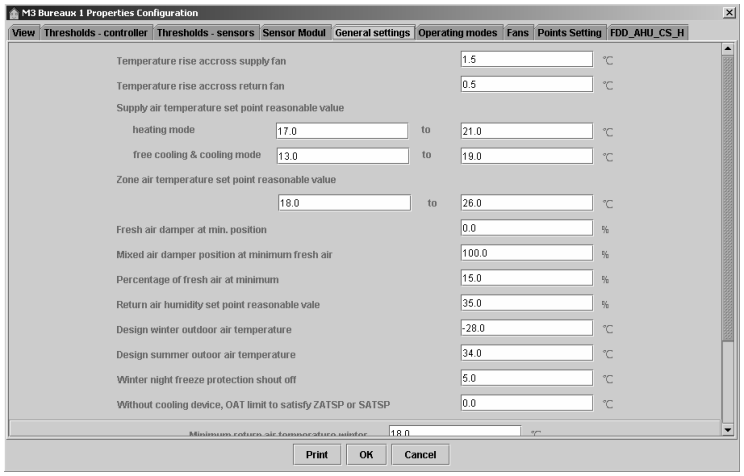
- Could be constant or dynamic
- User define
- User define with DABO tool
- Calculate by DABO (Statistic, clustering method, etc.)

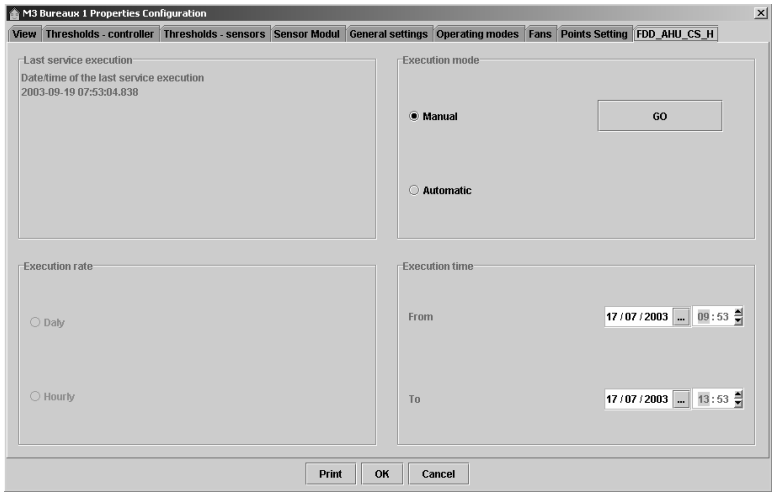

CTEC. Building Automation System
Building View
Java version designed by Elena Andrianova; CTEC-Varennes; t..(450)652-4715
BAS
Building-Varennes
OutdoorCondition
M3C Bureaux 2
406
402
403
404
405
M3 Bureaux 1
FreshAirSection
CoilAirSection
SupplyAirSection
AirFilter
Humidifier
Temperature
AirFlow
Humidity
CO2
Pressure
links
ReturnAirSection
MixecAirSection
ExhaustAirSection
SupplyFan
ReturnFan
ExternTemperature
links
1215
1219
1319
M2 Laboratoires
Lab1
Lab6
Graphic View
Building-Varennes :
M5 Salle électrique
M1 Usine pilote 1
M32 Salle Mécanique 2
M31 Usine pilote 2
M21E1
AHU 1107
M4 Corridor
M20E1
M6 Salle des chaudières
M30E1
Boiler
M30 Bureaux 2
M3E2
M3E3
M3E1
M3 Bureaux 1
OutdoorCondition
M10 chambre climatique
Lab1

Diagnostic Agent for Building operators (DABO)



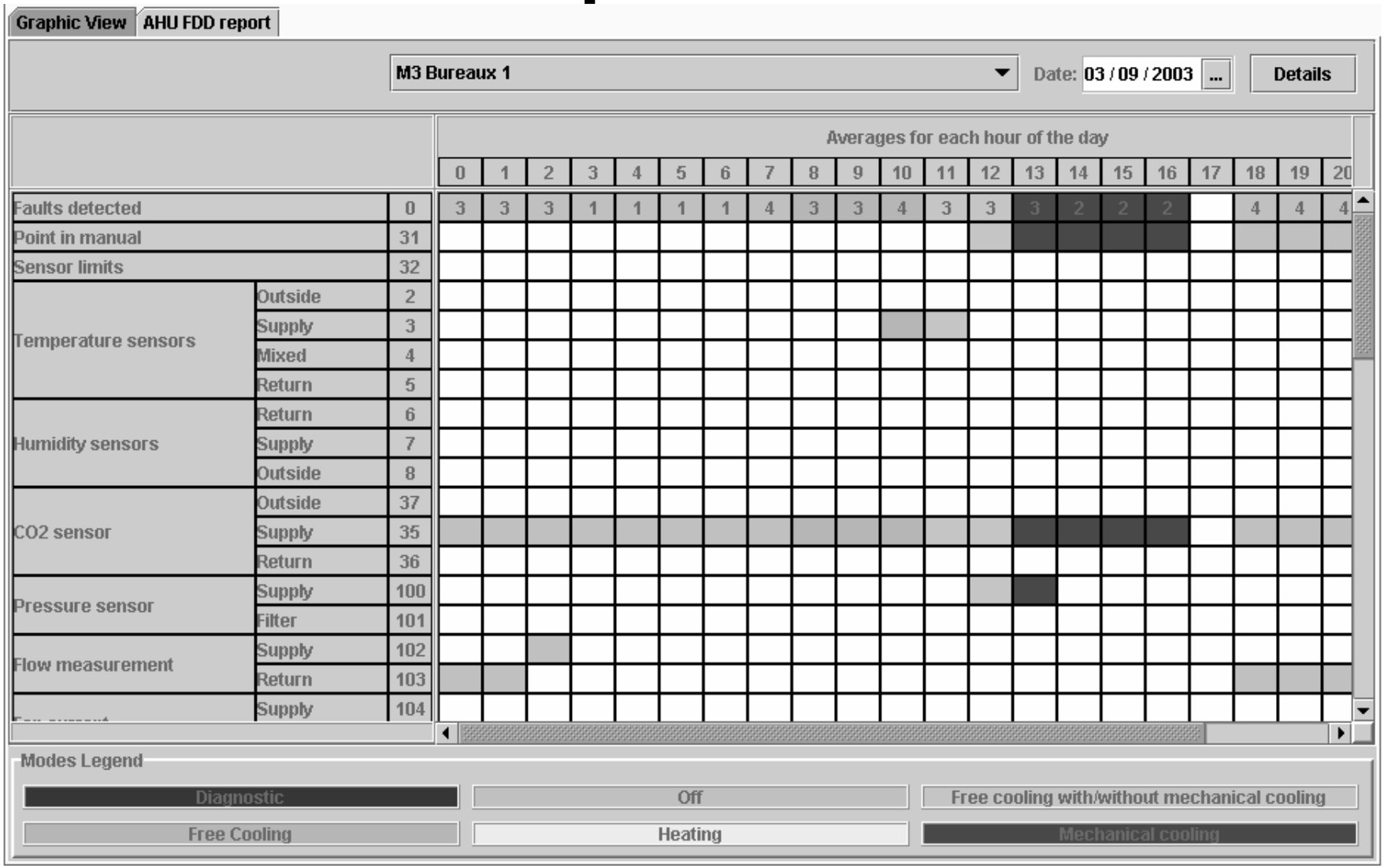






Demonstration Projects

FDD report for AHU



MAT uncalibrated by – 3°C

M30 Bureaux 2 - 2003-09-25 at 15h

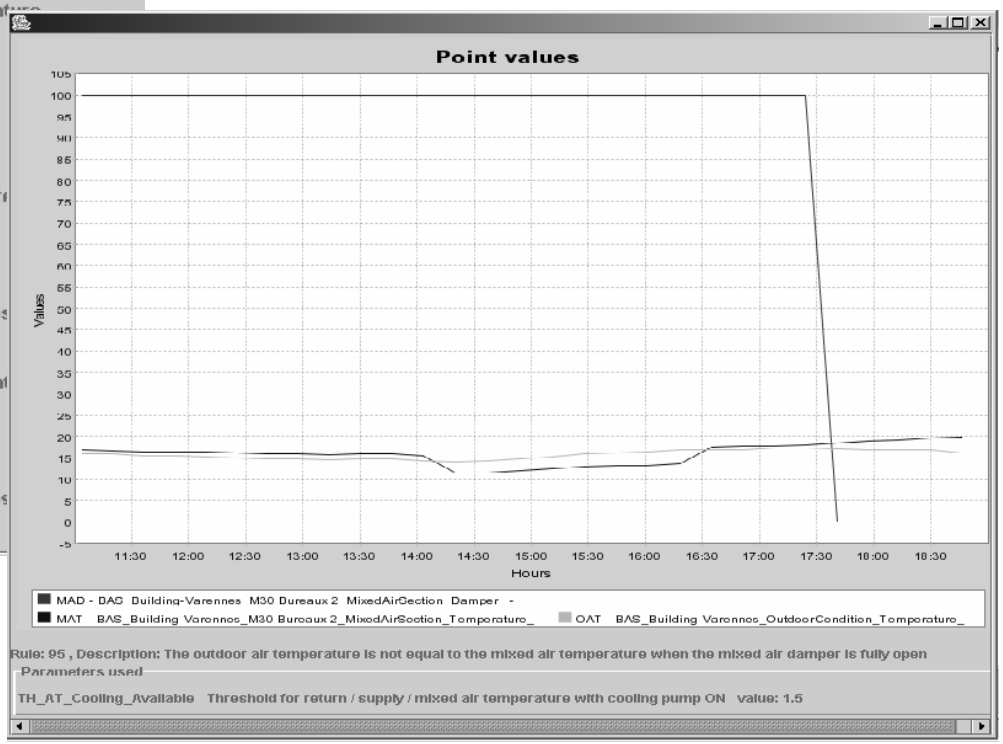
Fault 3: Supply air temperature sensor
Mode: Free cooling with/without mechanical cooling
Suggested action: Verify calibration of temperature sensor
Impact: Possibility of overcooled or overheated air temperature causing
room temperature control and increased terminal reheat if applicable
Rule 89: The supply air temperature is higher then the mixed air temperature and
cooling coil valve is open

Fault 4: Temperature Sensors: Mixed
Mode: Free cooling with/without mechanical cooling
Suggested action: Verify calibration of temperature sensor or too much air stratification
Impact: Provide incorrect supply air temperature during free cooling and
system shut down as a freeze stat protection
Rule 09: The supply air temperature is higher then the mixed air temperature and
cooling coil valve is open
Rule 95: The outdoor air temperature is not equal to the mixed air temperature
the mixed air damper is fully open

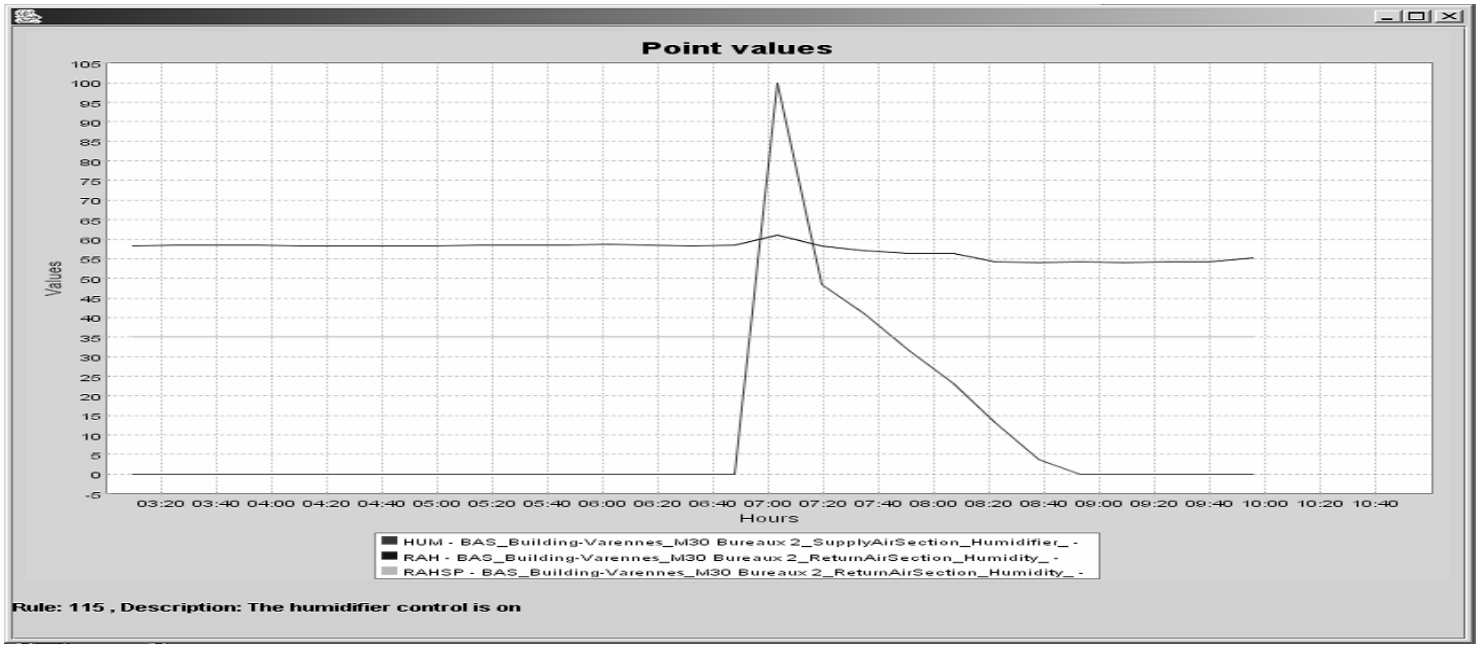
Fault 5: Return air temperature sensor
Mode: Free cooling with/without mechanical cooling
Suggested action: Verify calibration of temperature sensor
Impact: Misrepresentation of zone temperatures leading to improper temperature
of supply air set point
Rule 91: The return air temperature is lower then the allowable minimum r
temperature during free cooling

Fault 13: Mixed air damper failure
Mode: Free cooling with/without mechanical cooling
Suggested action: Verify damper, linkage, actuator, adjustment and leakage when clos
Impact: Reduction in free cooling capacity if stuck open and possibility of
up if stuck closed
Rule 95: The outdoor air temperature is not equal to the mixed air temperat
the mixed air damper is fully open

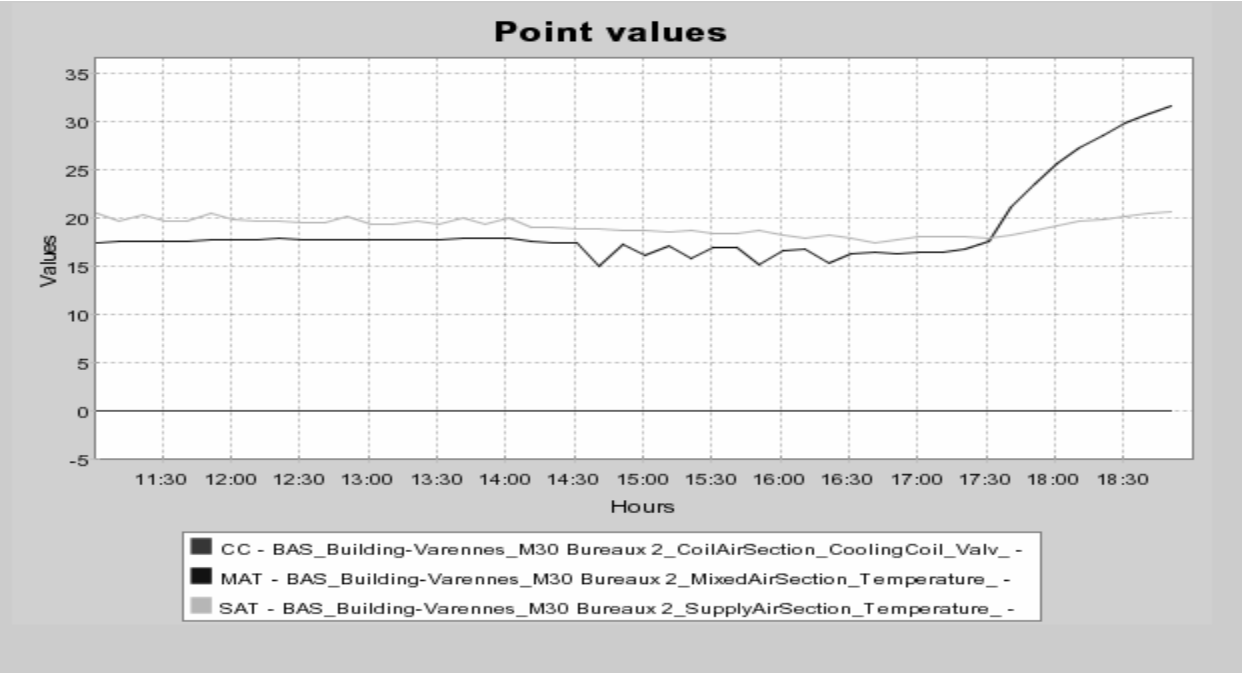
Fault 14: Outdoor air damper failure
Mode: Free cooling with/without mechanical cooling
Suggested action: Verify damper, linkage, actuator, adjustment and leakage when clos
Impact: Reduction in free cooling capacity if stuck closed and possibility of
up if stuck open



AHU-Fault: Wrong Humidifier Command



AHU Heating Valve Leak



AHU fault details

M30 Bureaux 2 - 2003-12-17 at 15h

Fault 24: Heating valve failure

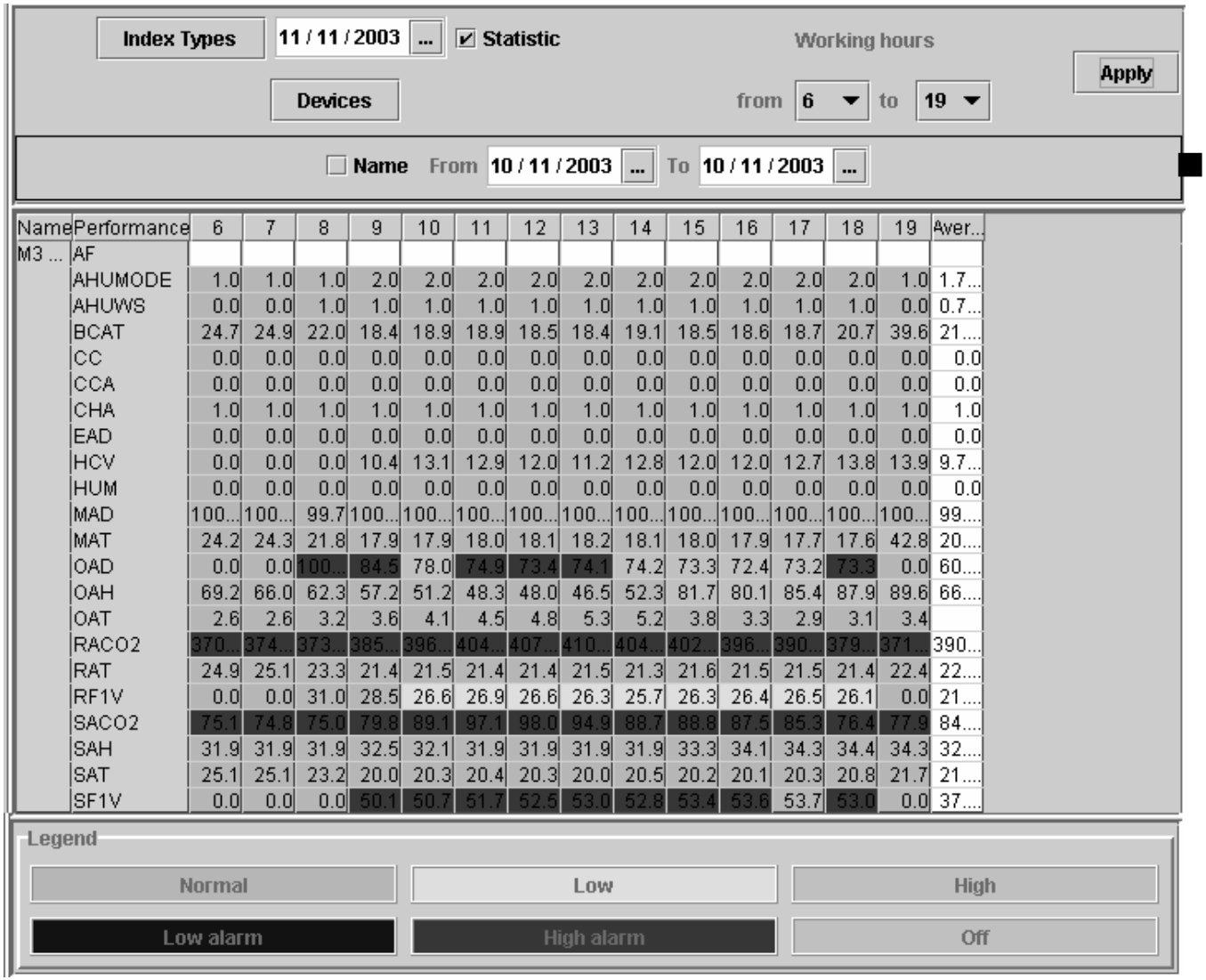
Mode: Free Cooling

Suggested action: Verify damper, linkage, actuator, adjustment and leakage when closed

Impact: No control of heating coil, therefore no control of supply air temperature

Rule 97: The supply air temperature is higher then the mixed air temperature the cooling coil valve is closed

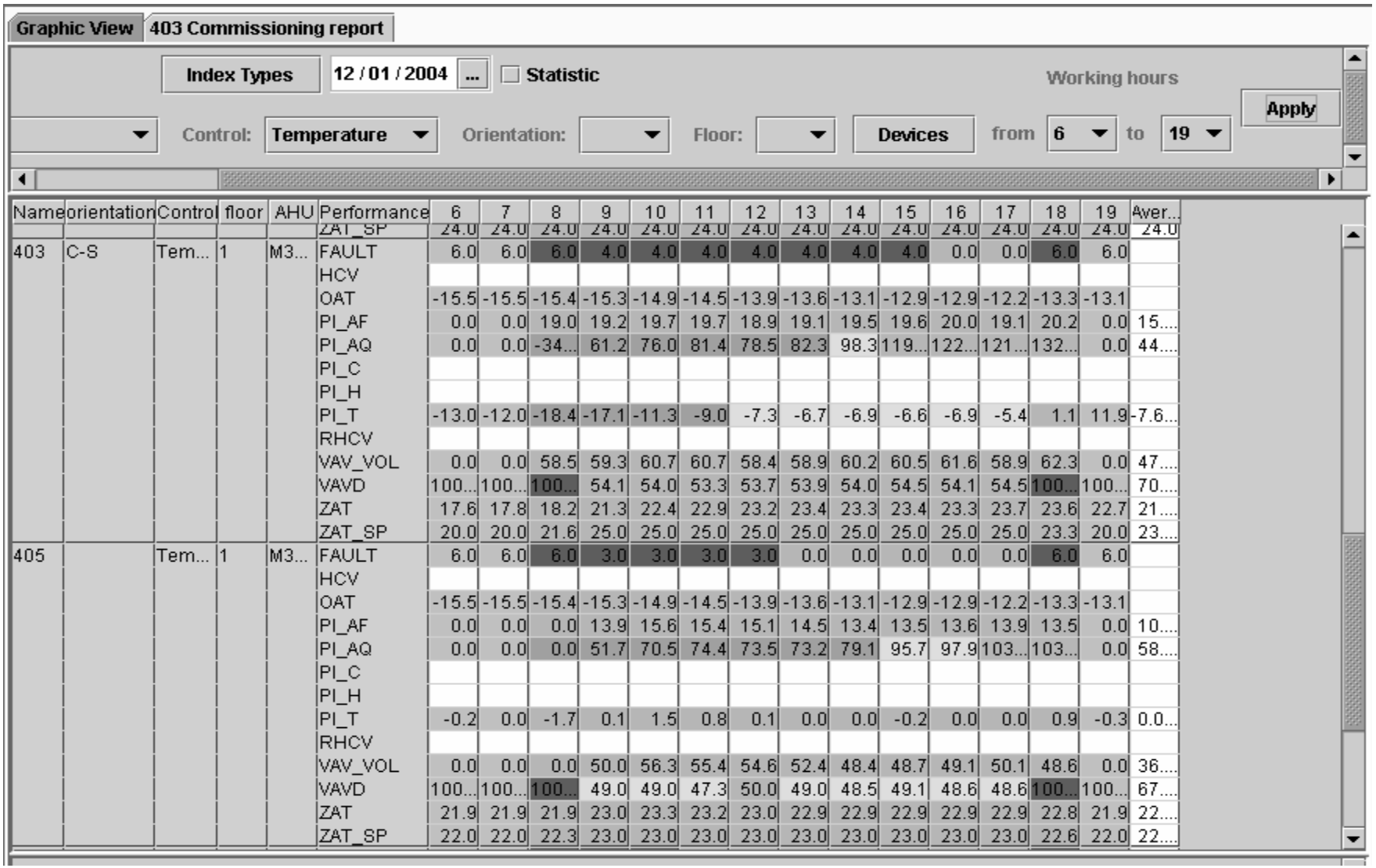
General Visual Report Structure



Name	Performance	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Aver...
M3 ...	AF															
	AHUMODE	1.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.7...
	AHUWS	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.7...
	BCAT	24.7	24.9	22.0	18.4	18.9	18.9	18.5	18.4	19.1	18.5	18.6	18.7	20.7	39.6	21....
	CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	CCA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	CHA	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	EAD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	HCV	0.0	0.0	0.0	10.4	13.1	12.9	12.0	11.2	12.8	12.0	12.0	12.7	13.8	13.9	9.7...
	HUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	MAD	100...	100...	99.7	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...	99....
	MAT	24.2	24.3	21.8	17.9	17.9	18.0	18.1	18.2	18.1	18.0	17.9	17.7	17.6	42.8	20....
	OAD	0.0	0.0	100...	84.5	78.0	74.9	73.4	74.1	74.2	73.3	72.4	73.2	73.3	0.0	60....
	OAH	69.2	66.0	62.3	57.2	51.2	48.3	48.0	46.5	52.3	81.7	80.1	85.4	87.9	89.6	66....
	OAT	2.6	2.6	3.2	3.6	4.1	4.5	4.8	5.3	5.2	3.8	3.3	2.9	3.1	3.4	
	RACO2	370...	374...	373...	385...	396...	404...	407...	410...	404...	402...	396...	390...	379...	371...	390...
	RAT	24.9	25.1	23.3	21.4	21.5	21.4	21.4	21.5	21.3	21.6	21.5	21.5	21.4	22.4	22....
	RF1V	0.0	0.0	31.0	28.5	26.6	26.9	26.6	26.3	25.7	26.3	26.4	26.5	26.1	0.0	21....
	SACO2	75.1	74.8	75.0	79.8	89.1	97.1	98.0	94.9	88.7	88.8	87.5	85.3	76.4	77.9	84....
	SAH	31.9	31.9	31.9	32.5	32.1	31.9	31.9	31.9	31.9	33.3	34.1	34.3	34.4	34.3	32....
	SAT	25.1	25.1	23.2	20.0	20.3	20.4	20.3	20.0	20.5	20.2	20.1	20.3	20.8	21.7	21....
	SF1V	0.0	0.0	0.0	50.1	50.7	51.7	52.5	53.0	52.8	53.4	53.6	53.7	53.0	0.0	37....

- Filters:
  - Devices (one or all)
  - Control points
  - Indices
  - Date
  - Outside air temperature
  - Outside air humidity
  - Solar (if sensor is available)

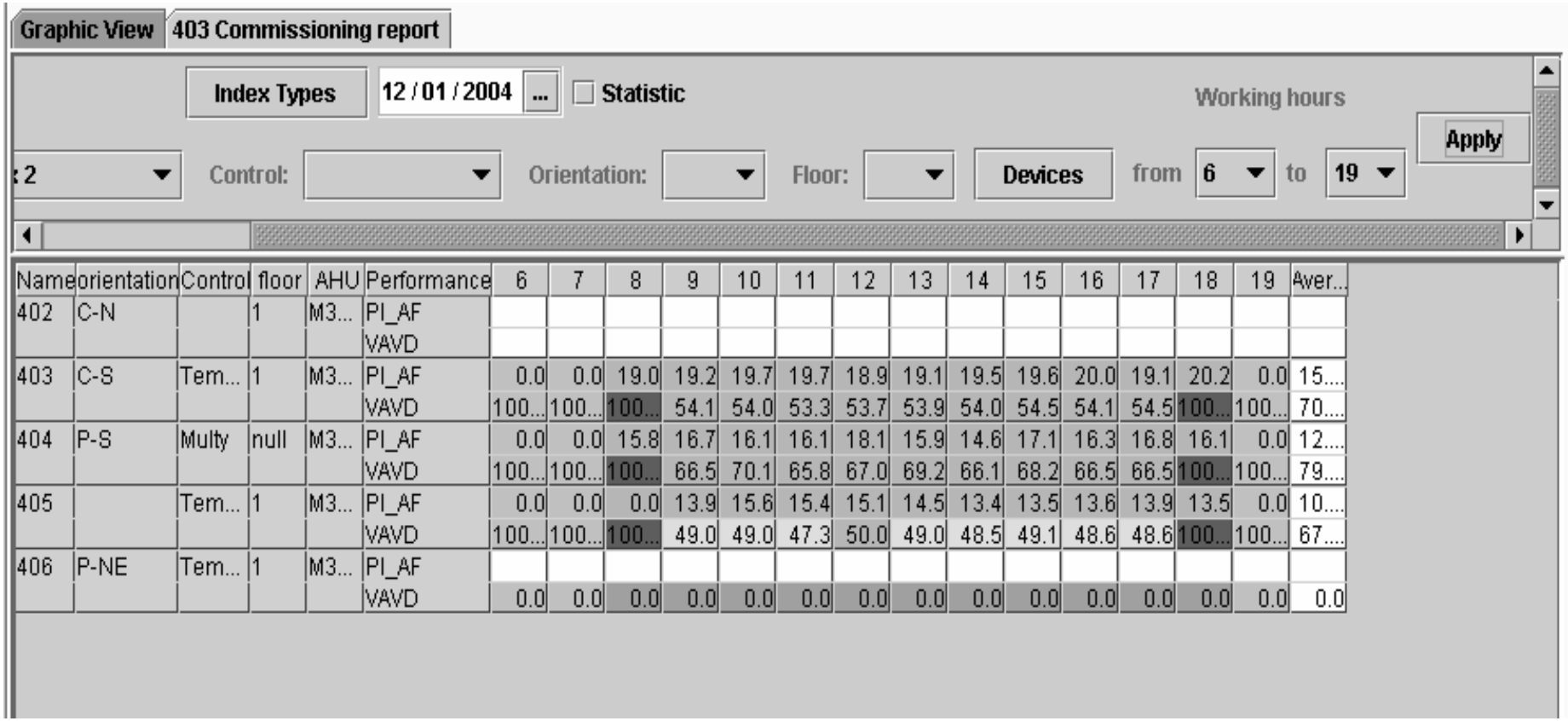
Daily Room Device Performance Report



Name	orientation	Control	floor	AHU	Performance	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Aver...
					ZAT_SP	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
403	C-S	Tem...	1	M3...	FAULT	6.0	6.0	6.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0	6.0	6.0	
					HCV															
					OAT	-15.5	-15.5	-15.4	-15.3	-14.9	-14.5	-13.9	-13.6	-13.1	-12.9	-12.9	-12.2	-13.3	-13.1	
					PI_AF	0.0	0.0	19.0	19.2	19.7	19.7	18.9	19.1	19.5	19.6	20.0	19.1	20.2	0.0	15....
					PI_AQ	0.0	0.0	-34...	61.2	76.0	81.4	78.5	82.3	98.3	119...	122...	121...	132...	0.0	44....
					PI_C															
					PI_H															
					PI_T	-13.0	-12.0	-18.4	-17.1	-11.3	-9.0	-7.3	-6.7	-6.9	-6.6	-6.9	-5.4	1.1	11.9	-7.6...
					RHCV															
					VAV_VOL	0.0	0.0	58.5	59.3	60.7	60.7	58.4	58.9	60.2	60.5	61.6	58.9	62.3	0.0	47....
					VAVD	100...	100...	100...	54.1	54.0	53.3	53.7	53.9	54.0	54.5	54.1	54.5	100...	100...	70....
					ZAT	17.6	17.8	18.2	21.3	22.4	22.9	23.2	23.4	23.3	23.4	23.3	23.7	23.6	22.7	21....
					ZAT_SP	20.0	20.0	21.6	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	23.3	20.0	23....
405		Tem...	1	M3...	FAULT	6.0	6.0	6.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	6.0	6.0	
					HCV															
					OAT	-15.5	-15.5	-15.4	-15.3	-14.9	-14.5	-13.9	-13.6	-13.1	-12.9	-12.9	-12.2	-13.3	-13.1	
					PI_AF	0.0	0.0	0.0	13.9	15.6	15.4	15.1	14.5	13.4	13.5	13.6	13.9	13.5	0.0	10....
					PI_AQ	0.0	0.0	0.0	51.7	70.5	74.4	73.5	73.2	79.1	95.7	97.9	103...	103...	0.0	58....
					PI_C															
					PI_H															
					PI_T	-0.2	0.0	-1.7	0.1	1.5	0.8	0.1	0.0	0.0	-0.2	0.0	0.0	0.9	-0.3	0.0...
					RHCV															
					VAV_VOL	0.0	0.0	0.0	50.0	56.3	55.4	54.6	52.4	48.4	48.7	49.1	50.1	48.6	0.0	36....
					VAVD	100...	100...	100...	49.0	49.0	47.3	50.0	49.0	48.5	49.1	48.6	48.6	100...	100...	67....
					ZAT	21.9	21.9	21.9	23.0	23.3	23.2	23.0	22.9	22.9	22.9	22.9	22.9	22.8	21.9	22....
					ZAT_SP	22.0	22.0	22.3	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	22.6	22.0	22....

Room Device optimisation report

(To reset AHU Supply air pressure setpoint)



Graphic View | 403 Commissioning report

Index Types | 12 / 01 / 2004 ... | Statistic | Working hours | Apply

: 2 | Control: | Orientation: | Floor: | Devices | from 6 to 19

Name	orientation	Control	floor	AHU	Performance	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Aver...
402	C-N		1	M3...	PI_AF															
					VAVD															
403	C-S	Tem...	1	M3...	PI_AF	0.0	0.0	19.0	19.2	19.7	19.7	18.9	19.1	19.5	19.6	20.0	19.1	20.2	0.0	15....
					VAVD	100...	100...	100...	54.1	54.0	53.3	53.7	53.9	54.0	54.5	54.1	54.5	100...	100...	70....
404	P-S	Multy	null	M3...	PI_AF	0.0	0.0	15.8	16.7	16.1	16.1	18.1	15.9	14.6	17.1	16.3	16.8	16.1	0.0	12....
					VAVD	100...	100...	100...	66.5	70.1	65.8	67.0	69.2	66.1	68.2	66.5	66.5	100...	100...	79....
405		Tem...	1	M3...	PI_AF	0.0	0.0	0.0	13.9	15.6	15.4	15.1	14.5	13.4	13.5	13.6	13.9	13.5	0.0	10....
					VAVD	100...	100...	100...	49.0	49.0	47.3	50.0	49.0	48.5	49.1	48.6	48.6	100...	100...	67....
406	P-NE	Tem...	1	M3...	PI_AF															
					VAVD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Daily AHU Performance Report

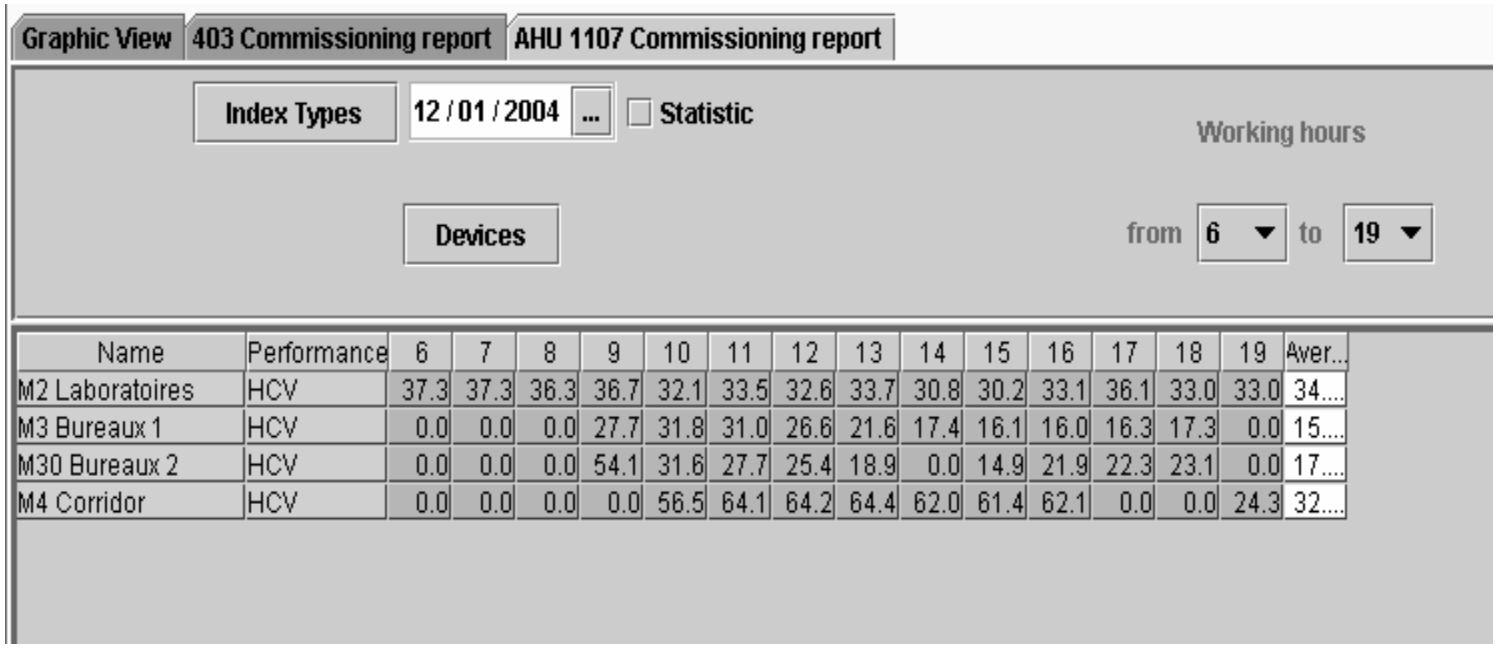
Index Types | 12 / 01 / 2004 ... | Statistic | Working hours

Devices | from 6 to 19

Name	Performance	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Aver...
M3 Bureaux 1	AFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	AHUMODE	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.7...
	AHUWS	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.7...
	CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	EAD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	ENTH	32.3	32.3	29.8	28.3	29.9	31.4	32.3	33.1	33.7	34.4	34.3	34.0	34.2	36.4	32....
	HCV	0.0	0.0	0.0	27.7	31.8	31.0	26.6	21.6	17.4	16.1	16.0	16.3	17.3	0.0	15....
	HUM	0.0	0.0	0.0	100...	100...	98.3	100...	100...	100...	98.3	100...	100...	100...	0.0	71....
	MAD	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...	100...
	MAT	22.6	22.6	22.7	13.0	13.5	14.0	14.8	15.4	15.6	15.9	15.7	15.8	16.0	20.1	17....
	OAF															
	OAT	-15.5	-15.5	-15.4	-15.3	-14.9	-14.5	-13.9	-13.6	-13.1	-12.9	-12.9	-12.2	-13.3	-13.1	
	RACO2	372...	374...	374...	398...	449...	491...	499...	491...	488...	497...	506...	499...	472...	441...	454...
	RAT	22.7	22.6	21.2	18.7	19.4	20.4	20.8	21.2	21.5	21.8	21.9	21.7	21.5	22.9	21....
	RF1	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.7...
	RF1V	0.0	0.0	28.8	24.6	23.4	29.5	37.1	40.0	40.2	40.5	40.5	40.5	38.3	0.0	27....
	SAH	29.2	29.2	30.2	38.4	39.3	41.9	41.2	42.1	42.9	43.5	44.5	43.8	44.6	41.9	39....
	SAT	23.3	23.4	21.6	18.3	19.0	19.1	19.4	19.4	19.2	19.2	18.8	19.0	18.8	20.3	19....
	SATSP	17.4	17.3	17.9	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	18.9	19.0	16.4	18....
	SF1	0.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.7...
	SF1V	0.0	0.0	40.6	40.8	40.6	44.4	49.1	51.1	52.4	53.2	52.1	51.3	49.5	0.0	37....

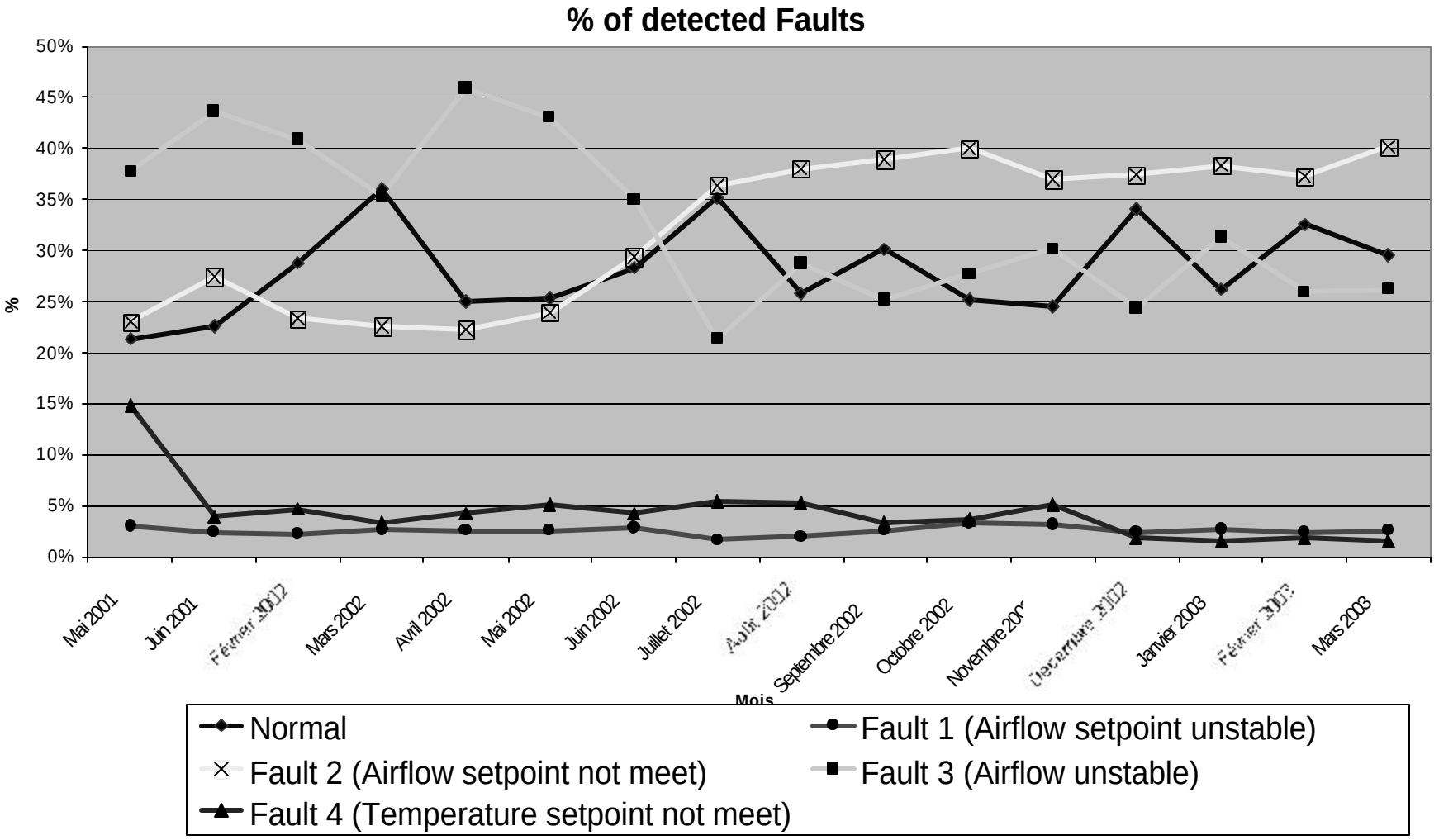
AHU Optimiser Report:

(To optimize heating supply water temperature)

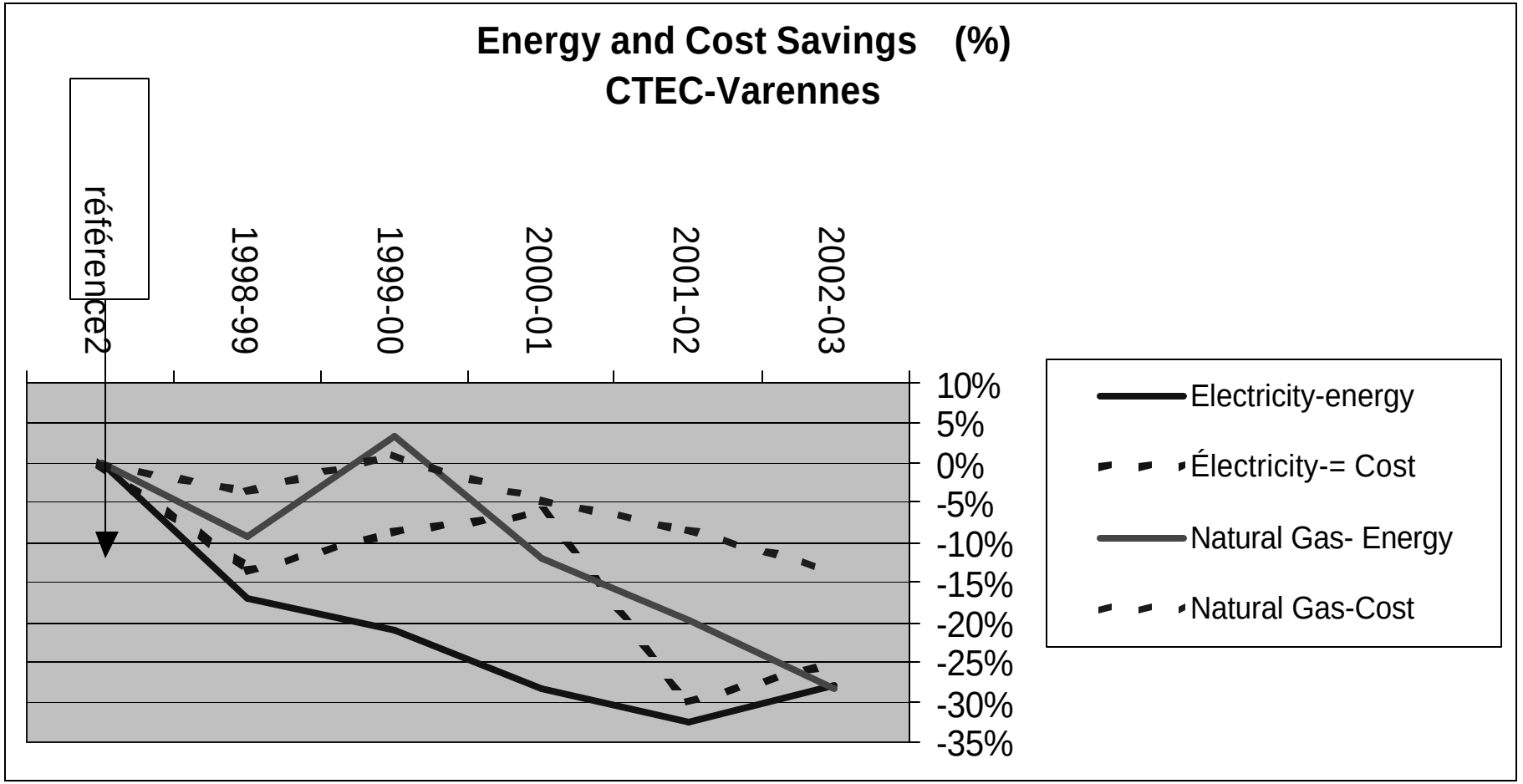


Name	Performance	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Aver...
M2 Laboratoires	HCV	37.3	37.3	36.3	36.7	32.1	33.5	32.6	33.7	30.8	30.2	33.1	36.1	33.0	33.0	34....
M3 Bureaux 1	HCV	0.0	0.0	0.0	27.7	31.8	31.0	26.6	21.6	17.4	16.1	16.0	16.3	17.3	0.0	15....
M30 Bureaux 2	HCV	0.0	0.0	0.0	54.1	31.6	27.7	25.4	18.9	0.0	14.9	21.9	22.3	23.1	0.0	17....
M4 Corridor	HCV	0.0	0.0	0.0	0.0	56.5	64.1	64.2	64.4	62.0	61.4	62.1	0.0	0.0	24.3	32....

VAV FDD Report
200 Dual Duct VAV Boxes



Energy and Cost savings



EMCS Assisted Commissioning Tool

- Monitors building control data
  - Could invoke sequence of tests
  - Normal operating data
- Performs advanced data analyses
- Detects faults, performs diagnosis and reports energy performance
- Generates detailed reports
- Implemented in stand-alone tools and/or embedded in EMCS

Next Steps

- Fine tuned expert rules in FDD-Component level
- Complete the FDD-System level
- Analysis of Demonstration project results

FDD Report For VAV Boxes